CLAIMS

1. An assembly comprising:

a first pump/motor having a first drive plate assembly rigidly coupled to a shaft, the first drive plate assembly being in hard contact with a first end surface of the shaft in a plane perpendicular to a longitudinal axis of the shaft; and

a second pump/motor having a second drive plate assembly rigidly coupled to the shaft and in hard contact with a second end surface of the shaft in a plane perpendicular to the longitudinal axis of the shaft, the first and second drive plate assemblies and shaft acting as a substantially solid element when under compression to cancel axial loads generated by the first and second pump/motors through the shaft.

2. The assembly according to claim 1 wherein the first drive plate assembly has a first drive plate, an inner surface of the first drive plate being in hard contact with the first end surface of the shaft, and the second drive plate assembly has a second drive plate, an inner surface of the second drive plate being in hard contact with the second end surface of the shaft.

3. The assembly according to claim 1 wherein the first drive plate assembly includes a first pump/motor shaft having a first annular surface in a plane perpendicular to the longitudinal axis of the shaft and the second drive plate assembly includes a second pump/motor shaft having a second annular surface in a plane perpendicular to the longitudinal axis of the shaft, and the first and second pump/motor shafts are rigidly connected to the shaft such that the first annular surface is in hard contact with the first end surface of the shaft and the second annular surface is in hard contact with the second end surface of the shaft.

4. The assembly according to claim 1, further comprising a first gap provided between the first drive plate assembly and a first annular bearing provided on the shaft, a spacer being provided in the first gap to just contact the first drive plate assembly and the first annular bearing, and further comprising a second gap provided between the second drive plate assembly

and a second annular bearing provided on the shaft, a second spacer being provided in the second gap to just contact the second drive plate assembly and the second annular bearing.

5. The assembly according to claim 4 wherein the spacer is a shim, bushing, spring, or any other similar device.

6. The assembly according to claim 4 wherein the first annular bearing is located by a first outer race provided in a housing surrounding the assembly, and the first outer race is provided in the housing at a selected position to locate the first annular bearing at a predetermined position that is spaced longitudinally from the first drive plate to form the first gap, and the second annular bearing is located by a second outer race provided in the housing, the second outer race being provided in the housing at a selected position to locate the second annular bearing at a predetermined position that is spaced longitudinally from the second drive plate to form the second gap.

7. The assembly according to claim 1 wherein a torque transferring assembly is coupled to the shaft, the torque transferring assembly generating a first radial force in a first direction, and the first and second pump/motors are oriented to ensure that when the first and second pump/motors stroke, they each generate a second radial force in a second direction, the second direction being opposite to the first direction.

8. An assembly comprising:

a first pump/motor having a first drive plate assembly rigidly coupled to and in hard contact with a first end surface of a shaft in a plane perpendicular to a longitudinal axis of the shaft;

a second pump/motor having a second drive plate assembly rigidly coupled to and in hard contact with a second end surface of the shaft in a plane perpendicular to a longitudinal axis of the shaft;

a first annular bearing coupled to the shaft, the first drive plate assembly being in light contact only with the first annular bearing; and

a second annular bearing coupled to the shaft, the second drive plate assembly being in light contact only with the second annular bearing.

9. The assembly according to claim 8 wherein the first drive plate assembly has a first drive plate, an inner surface of the first drive plate being in hard contact with the first end surface of the shaft, and the second drive plate assembly has a second drive plate, an inner surface of the second drive plate being in hard contact with the second end surface of the shaft.

10. The assembly according to claim 8 wherein the first drive plate assembly includes a first pump/motor shaft having a first annular surface in a plane perpendicular to the longitudinal axis of the shaft and the second drive plate assembly includes a second pump/motor shaft having a second annular surface in a plane perpendicular to the longitudinal axis of the shaft, and the first and second pump/motor shafts are rigidly connected to the shaft such that the first annular surface is in hard contact with the first end surface of the shaft and the second annular surface is in hard contact with the second end surface of the shaft.

11. The assembly according to claim 8, further comprising a first gap provided between the first drive plate assembly and the first annular bearing, a first spacer being provided in the first gap to just contact the first drive plate assembly and the first annular bearing, and further comprising a second gap provided between the second drive plate assembly and the second annular bearing, a second spacer being provided in the second gap to just contact the second drive plate assembly and the second annular bearing.

12. The assembly according to claim 11 wherein the spacer is a shim, bushing, spring, or any other similar device.

13. The assembly according to claim 8 wherein the first annular bearing is located by a first outer race provided in a housing surrounding the assembly, and the first outer race is provided in the housing at a selected position to locate the first annular bearing at a predetermined position that is spaced longitudinally from the first drive plate to form a first gap, and the second annular bearing is located by a second outer race provided in the housing, the second outer race being provided in the housing at a selected position to locate the second annular bearing at a predetermined position that is spaced longitudinally from the second drive plate to form a second gap.

14. The assembly according to claim 13, further comprising a first spacer provided in the first gap, the first spacer having a thickness sufficient to just bridge the distance between the first drive plate and the first annular bearing, and a second spacer provided in the second gap, the second spacer having a thickness sufficient to just bridge the gap between the second drive plate and the second annular bearing.

15. The assembly according to claim 8 wherein at least one of the first and the second annular bearings is a tapered bearing, and an axial preload is applied to the tapered bearing.

16. The assembly according to claim 15 wherein the axial preload is applied by positioning a spring loading device between at least one of the first annular bearing and the first drive plate assembly or the second annular bearing and the second drive plate assembly.

17. The assembly according to claim 15 wherein the axial preload is applied by providing that a size of the first pump/motor is different than a size of the second pump/motor.

18. The assembly according to claim 15 wherein the axial preload is applied by stroking one of the first and second pump/motors to a lower displacement angle than the other of the first and second pump/motors.

19. An assembly comprising:

a first pump/motor and a second pump/motor coupled to a shaft;

a torque transferring device coupled to the shaft between the first and second pump/motors;

a first bearing coupled to the shaft between the first pump/motor and the torque transferring device and a second bearing coupled to the shaft between the second pump/motor and the torque transferring device;

a housing provided around the first and the second pump/motors, the first and the second bearings, and the torque transferring device; and

a first seal positioned between the first bearing and a first drive plate of the first pump/motor and a second seal positioned between the second bearing and a second drive plate of the second pump/motor.

20. The apparatus according to claim 19 wherein the first and the second seals divide the housing into a first, a second, and a third region, the first region containing the first pump/motor, the second region containing the torque transferring device and the first and the second bearings, and the third region containing the second pump/motor.

21. The apparatus according to claim 20 wherein the first and the third regions contain a sufficient volume of oil to operate the first and second pump/motors, and the second region contains a substantially lower volume of oil than in the first and the third regions.

22. The apparatus according to claim 20 wherein the volume of oil in the second region is sufficiently small to only splash lubricate the first and the second bearings.

23. An assembly comprising:

a first pump/motor and a second pump/motor coupled together via a shaft, and a torque transferring assembly coupled to the shaft, the torque transferring assembly generating a first radial force in a first direction, the first and second pump/motors being oriented to ensure that when the first and second pump/motors stroke, they each generate a second radial force in a second direction, the second direction being opposite to the first direction.

24. The assembly according to claim 23 wherein the torque transferring assembly includes a plurality of gears that transmit torque from the shaft to a second shaft.

25. A method of operating a plurality of pump/motors comprising:

coupling a first drive plate of a first pump/motor to one side of an input/output shaft;

coupling a second drive plate of a second pump/motor to an opposing side of the input/output shaft;

coupling a torque transferring device to the input/output shaft;

coupling a secondary shaft to the torque transferring device;

generating a separation force in a first direction when transferring torque to the secondary shaft; and

stroking the first pump/motor to generate a first radial force in a second direction and stroking the second pump/motor to generate a second radial force in the second direction, the second direction being opposite to the first direction.

26. A method for assembling two pump/motors comprising:

rigidly coupling a first drive plate of a first pump/motor to a second drive plate of a second pump/motor through one or more shafts;

positioning a first bearing adjacent to, yet longitudinally spaced from, the first drive plate to form a first gap;

positioning a second bearing adjacent to, yet longitudinally spaced from, the second drive plate to form a second gap;

positioning a first spacer in the first gap to just contact the first drive plate and the first bearing; and

positioning a second spacer in the second gap to just contact the second drive plate and the second bearing.

27. A method of improving the efficiency of two or more opposing pump/motors mounted on a common shaft, the method comprising:

coupling a first and a second pump/motor on a common shaft;

coupling a torque transferring device to the common shaft between the first and second pump/motors;

positioning a first bearing between the first pump/motor and the torque transferring device and positioning a second bearing between the second pump/motor and the torque transferring device;

housing the first and the second pump/motors, the first and the second bearings, and the torque transferring device in a common housing;

dividing the common housing into first, second, and third regions wherein the first and the third regions contain the first and second pump/motors, respectively, and the second region contains the torque transferring device, the first bearing, and the second bearing;

filling the first and the third regions with sufficient oil to operate the pump/motors; and

keeping the second region substantially sealed from the oil contained in the first and the third regions.

28. An apparatus for changing the displacement of a plurality of bent-axis piston machines at substantially the same rate, the apparatus comprising:

a first actuator arm coupled to a first bent-axis piston machine and coupled to or integrally formed with a first hydraulic piston positioned within a first chamber;

a second actuator arm coupled to a second bent-axis piston machine and coupled to or integrally formed with a second hydraulic piston positioned within a second chamber;

a control valve coupled to a hydraulic fluid source and selectively operable to substantially simultaneously deliver a volume of hydraulic fluid to the first and the second chambers; and

a mechanical link coupling the first and the second actuator arms.

29. The apparatus according to claim 28 wherein the first hydraulic piston divides the first chamber into a first upper region and a first lower region, and the second hydraulic piston divides the second chamber into a second upper region and a second lower region, and wherein the volume of hydraulic fluid is selectively delivered to either the first and second upper regions or the first and second lower regions to substantially simultaneously change the displacement angle of the first and second bent-axis piston machines.

30. An apparatus for changing the displacement of two bent-axis piston machines at substantially the same rate, the apparatus comprising:

a first actuator arm coupled to a first bent-axis piston machine, a displacement of the first bent-axis piston machine being changed by movement of the first actuator arm;

a second actuator arm coupled to a second bent-axis piston machine, a displacement of the second bent-axis piston machine being changed by movement of the second actuator arm; and

a mechanical link coupled to the first and the second actuator arms and selectively powered to move the first and second actuator arms substantially simultaneously.

31. The apparatus according to claim 30 wherein the mechanical link is powered by an electrical power source.

32. The apparatus according to claim 30 wherein the mechanical link is powered by a hydraulic power source.

33. The apparatus according to claim 30 wherein the mechanical link is powered by an ICE.

34. The apparatus according to claim 30 wherein the mechanical link is powered by a mechanical means.

35. An apparatus for changing the displacement of a plurality of bent-axis piston machines at substantially the same rate, the apparatus comprising:

a first actuator arm coupled to a first bent-axis piston machine and to a first gear rack;

a second actuator arm coupled to a second bent-axis piston machine and to a second gear rack; and

a shaft having a first gear coupled to the first gear rack and a second gear coupled to the second gear rack, the shaft being selectively powered to rotate, the first and second gear racks traveling with the rotation of the shaft to change the displacement of the bent-axis piston machines.

36. An apparatus comprising:

a first pump/motor;

a second pump/motor; and

control means for selectively changing a displacement of the first and second pump/motors simultaneously to a selected displacement angle.

37. An apparatus according to claim 36 wherein the control means includes feedback means to ensure that the pump/motors are stroked in unison.

38. An apparatus comprising:

a first pump/motor coupled to a first actuator, a displacement of the first pump/motor being selectively varied by moving the first actuator;

a second pump/motor coupled to a second actuator, a displacement of the second pump/motor being selectively varied by moving the second actuator; and

a control circuit with feedback loop coupled to the actuators, the control circuit selectively moving the first and second actuators substantially simultaneously to a desired position.

39. A method for changing the displacement of a plurality of bent-axis piston machines at substantially the same rate, the method comprising:

coupling a first actuator arm to a first bent-axis piston machine and to a mechanical link;

coupling a second actuator arm to a second bent-axis piston machine and to the mechanical link; and

selectively moving the mechanical link to a desired position.

40. A method for changing the displacement of a first and second pump/motor substantially simultaneously, comprising:

monitoring a location of the first pump/motor while moving the first pump/motor to a first desired position;

monitoring a location of the second pump/motor while moving the second pump/motor to a second desired position; and

adjusting a rate of motion of one or both of the pump/motors as needed to ensure that the first and second pump/motors move to the first and second desired positions substantially simultaneously.